History lessons

Harley, Trevor A.

Published in:
Rethinking History

DOI:
10.1080/13642529.2013.811812

Publication date:
2014

History lessons: What can we learn about history?

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Rethinking History, in press

Abstract

What can we learn from the past? This paper examines the nature of the past, and discusses the extent to which historical outcomes are robust over different starting conditions, using primarily the example of the origin of the Great War. It reviews the mathematical and psychological literature on complexity theory, and considers the idea that history can indeed in some circumstances be robust across initial conditions. I introduce the notion of a dynamic historical attractor to account for the way in which the past unfolds over time, and relate dynamic attractors to post-modern approaches to historical interpretation.

Keywords

complexity, chaos, dynamic historical attractors, alternative histories, causality, narrative, post-modernism

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Introduction

While everyone knows that the Great World War was caused by the assassination of the Archduke Franz Ferdinand in Sarajevo in June 1914, the details of how the assassination came about are less familiar. The Black Hand group's plan failed dismally: on seeing a policeman one conspirator lost his nerve, another felt compassion for the Duchess so did not shoot, and then a bomb thrown by another, Nedelijko Cabrinovic, bounced off the roof of the Archduke's car and only had the consequence of causing the Archduke's car to speed away, thereby foiling the attempts of the remaining conspirators. One of the members of the gang, Gavrilo Princip, however later stopped for a sandwich at Moritz Schiller's delicatessen. Just at the time he was munching away, the Archduke's car appeared, having just taken a wrong turn. In attempting to reverse, the car stalled, giving Princip the chance to shoot from just a few feet. Even then he had to rely on a bystander kicking a policeman on the knee as the policeman was attempting to disarm him. The rest is (a very complex, admittedly) history.

Of course the political situation in Europe at the time was tense, but most accounts of the Great War make the assassination of the Archduke the precipitating event of the conflict (e.g. Ponting, 2003; Taylor, 1963). It is therefore interesting to speculate about what would have happened if Princip had been less hungry, and had given the sandwich a miss, or more hungry, and sat down for lunch in a restaurant. Even if he had still stopped for his sandwich, suppose the driver hadn't taken a wrong turning, or hadn't stalled the car, or if the nearby policeman hadn't been kicked on the knee at the vital moment? The assassination would then probably never have happened. Even between the assassination and the outbreak of war there was a complex chain of diplomatic accidents, misunderstandings, blunderings, and interventions, that meant that world war was not the necessary consequence of the assassination (Ponting, 2003; Tuchman, 1962). After the war, analysts recognised the accidental nature of the spark of the "most famous wrong turn in history", and searched for more satisfying accounts, ranging from the train timetables (in Taylor's famous 1963 account of how preparations for militarisation led to an unstoppable chain of events once they were put in motion), to German unification under Bismarck and subsequent militarisation and aggression (Buchanan, 2000), to the recalcitrance of Austria-Hungary and Russia (Ponting, 2003). So it is dubious at best to say that the assassination *caused* the war.

If the assassination of the Archduke had not eventually succeeded, would the Great War eventually still have begun? How different would the past have been if this chain of accidents had turned out slightly differently? Is it really a case of, as the proverb goes, for the want of a nail, a shoe was lost ... and then the kingdom of Richard III was lost? Note that I am distinguishing between the past and history in referring to the past as the sequence of events that comprise the subject matter of history, and history as the study of and our knowledge of the past (Munslow, 2010).

This article is about how robust events are across a range of initial conditions. Does the past tend to converge on particular outcomes, or is it just a series of chance events?

The assassination of the Archduke and the origin of the Great War is a particularly clear-cut example of the role of chance in history, but it is by no means an isolated one. There are numerous examples of random small events influencing the greater course of great things: the rashness of the Saxon troops at the Battle of Hastings; the weather dispersing the Spanish Armada; the spread of the Black Death; the finely balanced situation of the Cuban missile crisis of October 1962; almost *ad nauseam*. Buchanan (2000), in his account of the physics of history, discusses the collapse of the Soviet Union in a similar vein, as well as financial collapses. The list is lengthy enough, even before we consider the consequences of chance events in prehistory and geological time, such as the impact of the meteorite that almost certainly contributed to the mass extinctions at the Cretaceous-Tertiary boundary. Furthermore, it is well known that major accidents usually result from an unfortunate combination of several factors: among the most studied, the Tenerife air disaster of March 1977, which resulted in 583 deaths following the collision of two Boeing 747s, arose out of a combination of flights being diverted to a small airport following a bomb alert, fog, delays, one flight taking off without clearance, another continuing to the wrong exit, and a simultaneous radio transmission disrupting radio contact, among several other contributing causes (see Brafman & Brafman, 2008).

The role of chance in determining the outcome of the past, and in particular how alternative futures hang in a fine balance measured with small events, is not a new topic. John Stuart Mill, in *On Liberty*, can be read as having recognised the issue in his famous discussion of how Protestantism was rooted out in Spain and Italy, and "most likely would have been so in England, had Queen Mary lived or Queen Elizabeth died". But these famous chance events are just the tip of an iceberg of randomness: we can tunnel back through a network of causal relations and ask specific questions such as what would have happened if Hitler's mother and father had never met, or if Ghengis Khan had been slightly less ambitious? The present is the result of millions of such events in the past, but need the present have turned out as it has?

Alternative histories, exploring these "what if" scenarios, themselves have a long history, both in non-fiction (e.g. Ferguson, 1998; Kershaw, 2008) and in fiction. The earliest known alternative history is Livy's speculative account of what would have happened had Alexander the Great led his army west instead of east. Ferguson presents a collection of several counterfactual histories, attempting to answer such questions as what if John Kennedy had lived, what if Nazi Germany had defeated the Soviet Union, and what if Britain had stood aside in 1914? Ferguson's introduction is called "Towards a chaotic theory of the past", suggesting that past events lie in the balance, with outcomes depending on whether the rider has a nail in his shoe or not.

There are far too many fictional examples of alternative histories to provide a comprehensive listing. Perhaps the most famous example is the Ray Bradbury (1952) short story *A sound of thunder,* in which a dinosaur-hunting time traveller accidentally kills a butterfly. On their return to the present, the travellers find that the past has been changed in subtle ways, with words spelled differently and a different President winning the election. That this story hinges on a butterfly is apt, given the following argument.

Could the past have been that different?

These alternative histories are more than entertaining: they address a fundamental issue in the study of history - how *robust* are historical outcomes to variations in the chain of events that lead to them? Could killing a butterfly many millions of years ago *really* change the future on the macroscopic level? If Princip had failed to assassinate the Archduke, would the Great War have been averted, or would different events nevertheless soon have led to its outbreak? Could the past, and therefore the future, really have been that different? I will argue that it depends on the particularities of the situation, and introduce the notion of a *dynamic historical attractor*, a state to which events are drawn but that changes with time. In doing so I will raise questions about the nature of historical cause and explanation. I will also discuss how the description of attractors become entwined with the processes of forming a narrative which is the process we call history.

We can broadly divide historians into two types (I apologise if I caricature). Chaos casts light on the broad question of whether there is a meaningful analysis of the past to be made in terms of causes, or whether the best we can do is to tell a story, recognising that we bring our prejudices and beliefs to that story. We can call the first the "grand story" or "social science" approach (e.g. Diamond & Robinson, 2011; Lloyd, 1993; McCullagh, 1984, 1998, 2000, 2004; Roberts, 1996; Snooks, 1988), and contrast it with the post-modernist approach (e.g. Brown, 2005; Korhonen, 2006; White, 1973). At heart is the issue of whether it is possible to produce a meaningful, objective narration of the past that can be explicated in terms of structural causes and their consequences.

Events and time

The collective and individual past is made up of countless small events that might have turned out otherwise, each one of which has contributed to the state of the world as it is now. If instead these events had worked out just slightly differently, they could conceivably have led to a very different future. One consequence is that the distinction between major and minor events becomes blurred, and what is major and what is minor can only be distinguished in retrospect. Hence our historical narrative only gains meaning in its representation and interpretation, a perspective that fits within a post-modernist framework.

What though is an event? The concept needs considerable discussion. Some might conceptualise it as a "fact", but of course we know from philosophy of science that there is no such thing as a fact, only a theory (Lakatos, 1970). A similar perspective has been taken by Ankersmit (1994), who views the process of doing history as one of selecting and constructing a narrative. We define events *post hoc* by their significance; only in retrospect can we tell what events were and which were important (Munslow, 2000; Watts, 2011). For the sociologist Sewell, major historical events are not simply bigger than other events, but only acquire their significance via the transformations they enable. Sewell gives the example of the storming of the Bastille on 14 July 1789, which at first sight seems to be a highly significant historical event. But as Sewell points out the event only acquired true significance afterwards, as the National Assembly debated whether to condemn or to condone the violence. It was only when Louis XVI withdrew his troops and travelled to Paris that the event became truly significant. Even then the event acquired more significance in the light of what happened next. We are also left with the issue of the role of the steps that lead to the Storming of the Bastille. Where does one event end and another begin? There is no clear-cut answer; we can only form hypotheses when we parse the past. The other problem with constructing a narrative of events is of course that someone has to do the construction, and constructing a narrative necessarily means selecting and interpreting; there is no "ideal chronicler" upon whom to call (Danto, 1965; Watts, 2011).

We could instead define an event as a time slice, as the time is the framework within which events occur. But for historians the notion of time has for some time been in some respects even more troublesome; how small do we go when dividing it up? In physics, the smallest measure of time possible is the Planck time (defined as the time it takes one photon travelling at the speed of light to travel one Planck length, and is approximately 10^{-43} seconds; so there's been an awful lot of time in the past). The brevity of a unit of time such as this obviously makes its use clearly computationally intractable: we can't consider a future that has possible branches 10^{43} times a second. Instead we are left with constructing narratives about events and the conclusion that there is no straightforward formal definition of an event. We might however nevertheless know them when we see them.

How the past unfurls

I reiterate that I am distinguishing the *past* as a sequence of prior events and *history* as a means of studying the past, although this distinction is sometimes blurred. We can envisage two very different sorts of possible ways in which the past unfurls. The first way is that the past has a momentum so that most events won't change the course of the future: the eventual outcome will be the same regardless of differences in small events along the way. With this sort of view of history, the Great War would still have begun about the same time had Princip sat down to a hearty Wiener schnitzel and the Archduke not been assassinated that day. Or if Hitler's mother and father hadn't met, the conditions were still such that some other dictator would have come to the fore in Germany at about the same time. This stance sees the past rather as a heavy body moving along a path: you can perhaps deflect it the body little from its course, but it quickly resumes going on as it was before. I call this the *inertial* view of history. Tolstoy (1868) noted in *War and Peace* how great events (such as Napoleon's march on Moscow) take on an impetus of their own that becomes detached from their leaders and generals. In the inertial view there is linearity in the time course of events and a link between big causes and big effects. The inertial view is central to the social science approach to history.

The second possibility is that the course of the past is easily changed, in that causality is fragile and small differences in events can lead to very different historical outcomes. Some systems are chaotic in that very small differences in their starting state can lead to enormous and unpredictable differences in their later states; the example commonly given is how the flapping of a butterfly's wings in the Amazon can lead to a storm some time later in the northern hemisphere. It's known from economics that small, random differences in starting conditions can build into prolonged and sustained differences in the ways in which groups are perceived, and although the initial differences may be random, they nevertheless eventually become fossilised into substantial and permanent differences. For example, initially minor differences in opinion can lead to what appears to be major discrimination between groups (Fryer, Goeree, & Holt, 2005; Harford, 2008; Jared & Robinson, 2011). On this account, if Princip had had a mild stomach upset and given his sandwich a miss, WW I might never have begun, the Austrian-Hungarian Empire never collapsed, and England and Germany might have became staunch allies against Russia and France. The future would have been totally different. We can call this the *chaotic* view of history, where the past is merely "one damned thing after another" (Toynbee, 1957). To adopt this viewpoint does not mean to say that we must abandon notions of linearity and causality, just that it is hopeless to try to predict their outcomes. With the chaotic view all we can do is to tell a story of some kind after the event, so the chaos approach fits well with the post-modernist school of thought.

It is important here to consider the issue of determinism in history. Mathematical chaotic systems are completely deterministic, just not computationally usefully so, because minute variations in starting conditions can lead to completely different outcomes. So although the past (and future) might be in *principle* determined, in *practice* it is stochastic. Nevertheless, initial state sensitivity has implications for the type of history we pursue. Those pursuing "grand narratives" (e.g. Ferguson, 2011, in his discussion of how the west has triumphed because of its adoption of particular "apps", or Dugan and Dugan, 2000, on the roots of the industrial revolution), are most likely to come unstuck by the initial state-sensitivity of chaotic systems: it could easily be otherwise, particularly when we postulate theories on something as whimsical as human behaviour or motivation. I am not claiming that the initial state has no predictable consequences; the type of theorisation pursued by Jared Diamond in his (1997) analysis of why Europe became so dominant, discussing factors such how as the east-west long axis of Eurasia provided sufficient climatic similarity to permit the ready spread of agricultural advances compared with the north-south axis of the Americas, clearly shows that some initial conditions are particularly influential in determining what follows. To anticipate again, the geographical conditions of Eurasia made the West likely to succeed by shaping a very broad attractor for that outcome.

The question of whether the past is inertial or chaotic is much more than intellectual speculation: it's at the core of what history is about and how it should be studied. The rest of this article considers the alternative views of the past, and discusses a complex-systems approach to the subject.

Complexity, chaos, and dynamical systems

What is history? A convenient working dictionary definition is that history is the branch of knowledge that summarises and analyses past events. To take one prominent example of what the discipline of history is thought to do, the Wikipedia entry on history emphases that it should investigate the patterns of causes and effects that determine events. Within this framework, it is essential to explore the nature of the relationship between cause and event: is it possible to assign systematic, robust causes to events, or are the outcomes the chaotic whim of random circumstances? If the past and present are completely chaotic, so that very small changes along the way lead to very different outcomes in every situation, what sense does it make to talk of searching for patterns of causality? In short, if the sequence of past events is totally chaotic, there's little point in identifying causes, and we can't deduce any generalisations. Ferguson (1997, p. 89) states this view: “the search for universal laws of history is futile” (although on other occasions Ferguson appears to believe in such laws, e.g. Ferguson 2011). This argument is a very depressing one for historians, reducing the discipline to an over-intellectualised form of stamp collecting.

I am primarily concerned with the patterns of cause and effect. As stated above, I believe that the issue of whether the past is fully deterministic is totally irrelevant here. Laplace (1820) famously noted that “we ought to regard the present state of the universe as the effect of its antecedent state and as the cause of the state that is to follow”. That is, a suitably omniscient being could, given complete information about the current state of the world, and infinite computational resources, predict what is going to happen next; in other words, the future is fully determined by past events. Putting aside issues of quantum effects at the sub-microscopic level, history and the universe might run a deterministic, clockwork course, but this knowledge gets us nowhere. We are not omniscient beings with infinite resources. We need to rely on computers for simulations of even moderately complex physical systems. The problem of determining the future from an analysis of past and current conditions would appear to be intractable enough before we start considering chaos theory, which shows that extraordinarily small differences in the starting state can make huge and effectively unpredictable differences in subsequent states. Of course, this claim undermines the notion that we can learn from the past: there are no lessons from history. My question is to what extent historical macro-outcomes hinge on small events: can tiny differences make a big difference to historical outcomes? Is the past a non-linear system?

At this point it is useful to disentangle several related concepts that lie at the core of this examination. As Lewin (1993: p.14) points out, “there is tremendous scope for confusion over terms like *chaos* and *complexity*”.

A dynamical system is one that is time dependent; put more formally, we need to include a variable (*t*) to represent different states of the system at different times. The system can be described mathematically so that the state at $t+1$ follows from state t according to some equation. It might seem uncontroversial to say that complex systems are time-dependent, but time is often the forgotten variable in descriptions of complicated systems. Descriptions of psychological processes, for example, are often simplified by omitting time and by treating psychological processes as static systems. It's hard to imagine treating the past as a static system, but any account that treats the past as a snapshot or even series of unrelated snapshots could be said to be doing so. In history, we can say that the cause is what determines the state of the system at $t+1$ given its state at the prior time t. We also need to remember that we need to make an arbitrary decision about the size of the time slice captured by t, and our choice will have important consequences. Clearly the smaller the time slice the more often the system needs to be updated. (As noted above, I have worried about what is meant by time in history, as of course have others - e.g. Corfield, 2007; Ricoeur, 1990. Of course when describing the past several different time scales may be applicable. It doesn't make much sense to talk about individual years in geological time, or individual days in prehistory, but when we get to historic time days, hours, minutes, and even seconds can take on a critical aspect. The difference between living and dying, and hence the course of the future, might be a fraction of a second in battle or fleeing a natural disaster.)

My first argument is that we can learn important lessons about the nature of patterns of causality in the past by conceptualising it as a dynamical system.

A non-linear system is one whose output is not proportional to its input. A very simple real-life example of a non-linear system is a pile of sand. We can keep adding single grains of sand and the pile just keeps getting larger and larger; these additions of grains have linear effects. But then one more grain and there's suddenly an avalanche; that grain has had a non-linear effect. The change in state from t to $t+1$ caused by this particular grain is said to be *catastrophic*. Note that although the system is fully deterministic, and we know that at some point adding a further grain of sand will cause the pile to collapse, exactly which grain of sand causes the catastrophe is unpredictable. The avalanches are of varying sizes, distributed as a power law (Bak, Tang & Wiesenfeld, 1987). The parallels with the past here are I think obvious. Buchanan (2000) points to the ubiquity of the power law in natural systems. For example, the distribution of the number of deaths in wars plotted against the number of conflicts fits a near-perfect power law: every time you double the number of deaths in a conflict, wars of that size are four times less common (Buchanan, 2000; Richardson, 1960).

A complex system is a system whose properties are not apparent from the properties of its constituent parts; or, as defined by an editorial in *Science* in a special issue in April 1999, "one whose properties are not fully explained by an understanding of it component parts". (Note that there is considerable room for debate about what is meant by "explained".) Complex systems are often said to lie "at the edge of chaos". A chaotic system is one where the dynamics of the system are extremely sensitive to the initial conditions, or more generally to the conditions at time t. In effect in a chaotic system the behaviour at time $t+1$ appears random relative to the state at t. (Strictly speaking a function has to meet three conditions to be mathematically chaotic: it has to be sensitive to initial conditions, there has to be a very large number of possible outcomes, and the system cannot become trapped in the same small neighbourhood of outcomes for ever; see Ward, 2002, for a more detailed review). There is then a relation between complexity, chaos, and time, and although we might not agree about how exactly the terms are used, there is some understanding of how these things work.

Note that chaotic systems can arise from deceptively simple conditions. One of the simplest examples comes from the early work of Lorenz, who was running computer simulations of the weather. He found that the shortcut of entering 0.506 into the simulation instead of the full value of 0.506127 gave wildly different results (Gleick, 1987).

Here is a more complex example. The *logistic map function* is an example of a recurrence relation where each term of the sequence is defined by the preceding terms. Although it can be used to model aspects of population growth, the logistic map function has much wider application, and can be used as an example of how chaotic systems develop:

$$X(t+1) = n * x(t) * (1-x(t))$$

The logistic map produces a new output at t+1 iteratively as a function of x at time t. The value of n, called the growth factor, has curious effects on the value of x over time. When n is between 0 and 1, the value of x declines towards zero (the population tends to die out over time). When n is between 1 and 2 the value quickly stabilises on (n-1)/n, and when n is between 2 and 3 the population also stabilises on (n-1)/n, but oscillating around that value for some time. When n is between 3 and 3.45 (approximately), the population oscillates around two values for ever - these values are called *attractors*. Beyond 3.54, the number of attractors doubles as r increases, with 8, 16, 32 attractors, and so on. Around 3.57 the behaviour starts to become very unpredictable, although with some islands of periodicity and stability. But when $3.86<n<4$, the values of x over time are completely chaotic - although they are also completely deterministic. Beyond 4 the values leave the range [0,1] and become divergent (see Spivey, 2007, for more detail). Here very slight differences in the initial value of x lead to large and completely unpredictable differences in subsequent values as the function is iterated over time.

Well before this point I suspect the average historian will have at best said to themselves that this is all jolly interesting, but what have equations got to do with history? The past is so complex that it would appear to be ridiculous to attempt to reduce the pattern of events over time to any number of equations. Human past is so large, and affected by so many factors, that description in terms of even a tractably moderate number of nonlinear functions is impossible. There have of course been some very large-scale simulations, among the best known of which is the study of increasing population and dwindling resources by the Club of Rome (e.g. Meadows, Randers, & Meadows, 2004), but these are "toy" simulations - a term not intended to be derogatory - compared with the scale of the human past.

But another problem with human past is that it involves more than humans: even if we had a way of modelling human past in a tractable way, we would be foolish to restrict ourselves like this: we would ignore the physical world at our peril. The availability and distribution of natural resources, the climate, and geographical features, have of course all had an enormous influence on our development (Diamond, 1997), and will continue to do so, particularly with climate change, possible water shortages, and the dwindling of resources, particularly oil and gas, all of which might lead in the future to major international conflicts. Any comprehensive model of the past would need to include a representation of such physical features. Natural disasters have had a profound effect on our past and subsequent narrative of history; one only has to think of the effects of the Black Death in the mid-fourteenth century, which, in killing approximately a third of Europe's population, was arguably a prime cause of the collapse of the feudal system. A large meteorite could cause a catastrophe with little warning; a major earthquake could destroy a major city; a volcanic eruption could cause sudden global cooling; the Cumbre Vieja volcano on La Palma might collapse and send a catastrophic tsunami across the Atlantic; events such as these have all happened before, and will happen again. Such events are by their nature rare and largely unpredictable (although disasters follow a power law distribution if their magnitude is plotted against frequency), but could have significant effects on the course of the future.

It might therefore seem futile to attempt to analyse the past with a view to predicting the future or giving a detailed explanation of why things happened as they did. Psychologists flail around helplessly trying to explain the past or to predict the future behaviour of a single individual, and with the past we are dealing with a system of billions of individuals. Individual attempts to forecast the future are generally risible; one only has to consider the failure of most economists to predict the recent “credit crunch”. Books with titles including phrases such as “The end of history” (Fukuyama, 1992) soon met with widespread criticism - after all, events keep unfolding and what is history anyway? It’s known that groups of people can fare rather better in detecting patterns and predicting aspects of the future - the wisdom-of-the-crowd effect (Surowiecki, 2004). And while we cannot predict with any certainty what an individual might do, we can predict with some confidence the likely average behaviour of a group: for example, the suicide rate remains constant at around 32,000 a year in the USA (Smail, 2008). There are still limits to these methods; the mass wisdom of the world’s financial markets completely failed to predict war before or in 1914, showing no anxiety until late July (Ferguson, 2008, p. 298), and statistical averages are the result of physical processes in the past, not the cause.

What then could possibly be gained by attempting to model the past? My answer is that it provides a clearer understanding of the sorts of processes involved in change over time, and the restrictions (if there are any) on the sorts of causes that lead to different outcomes. Is there any lawfulness in the past, or is the unfolding of events completely chaotic? Does it even make sense to talk of searching for causes of how things have come to be? These are the types of profound questions that a dynamical systems approach can illuminate (see also Axelrod & Bennett, 1993; Ball, 2004; Buchanan, 2000).

Are there any means of distinguishing inertial from chaotic systems? Are there any reasons to suppose that the past is sensitive to the initial conditions? Chaotic systems are those which are very sensitive to initial conditions such that small differences in the current state can lead to very large differences in subsequent trajectories through state space. As we have seen with the logistic map, chaotic systems can arise from deceptively simple equations, although the equations must be non-linear. So the question becomes: what characterises stable, inertial systems from chaotic ones? Unfortunately there is no easy answer to this question. In the case of systems used to study the past, the situation is complicated further by our great difficulty in conceptualising the past mathematically, as noted above. Simply to reduce past physical processes to a position where we can discuss them meaningfully in these terms simplifies extensively and introduces assumptions that some historians may not find acceptable.

A few examples of personal history (I get killed in that crash) and global history (Princip has a sandwich or doesn't and the Archduke dies or lives) shows that locally the system must be at least partly chaotic. Small changes in the current state lead to unpredictable outcomes. The past is also non-linear: certain small events can have disproportionately large consequences (one mouthful nothing happens, another nothing happens, another ... the Archduke stops in front of you). Such moments, where minor perturbations can cause a complex system to shift from one state to another (e.g. peace to war) have become known colloquially as *tipping points* (Gladwell, 2000). Note that tipping points are not wholly unpredictable; there are sometimes early warning signs that phase transitions are possible (Scheffer et al., 2009). We attribute great importance to tipping points in the past, but as we can only recognise the significance of events and their consequences through the lens of hindsight, even they might be partly predictable in practice they gain their significance in our narration of history.

The interesting question is how chaotic is the system at the macro-level. Do the chaotic effects soon die out, with the inertia of the system taking over? In this case it does make sense to talk about laws and causes in history. Or do they instantly change the future? In which case it makes far less, if any, sense to talk about historical laws and causes.

Although the Bradbury view of history whereby one dead insect can change the future is a charming one, there is something implausible about it. While we could doubtless envisage fantastic scenarios where the future might hinge on such things, almost certainly it won't in fact matter. Indeed, many, probably most, events are not critical in the sense that if they happen or not, the future will soon carry on as it would have done. Whether I have grapes or cherries for breakfast is a local difference, but globally the course of my life resumes, and most of the time for the wider, global system small differences have no consequences at all - most of the time. Sadly, even if I die tomorrow, the course of the future of the world will probably continue largely unchanged. Perhaps depressingly, personal and global histories are mostly linear.

At first sight there appears to be a paradox here: on the one hand the flap of a butterfly's wings could start a hurricane across the globe, on the other whether I live or die might not matter very much at all (except to me). The key of course are these words "could" and "might". The system might be sensitive to initial conditions, but not always; according to the mathematics of the system then some events are more critical than others. In addition, some outcomes are more likely than others. It is well known that some configurations are more stable than others, and that some patterns of alliance between countries and other groups are more likely (e.g. Axelrod & Bennett, 1993, Ball, 2004). (Axelrod and Bennett showed through simulations that the most stable pattern of alliances in WWII is very close to what happened, with Germany and Italy on one side and Britain, France, and the Soviet Union on the other; however, another, nearly as stable configuration, would have seen the Soviet Union, Yugoslavia, and Greece lined up against Britain, France, Germany, and all the others. The model wasn't perfect however, consistently placing Germany in alliance with Poland.)

How can we steer a path between total chaos and total inertia? And how can we begin to formalise the concepts necessary to understand group (and indeed individual) history? Is there even any point in thinking about the past (e.g. see Jenkins, 2009)? I believe the answer is definitely "yes", and the key is to view the past as a temporal dynamics system and to introduce the notion of a historical attractor.

My approach combines two related notions: chaos and attractors. To introduce the overall idea, it's useful to begin with an analogy commonly used in neural networks. Let's think of the space of possible outcomes of the past, of what's going to happen next, as a landscape, with mountains, hills, valleys, and gorges. (In an early paper on attractor networks, Hinton and Shallice, 1991, talked about *basins* of attractions and *ravines* in the error surface. Energy landscapes are also used in physics as a way of visualising all the energy levels of a molecule in a Cartesian coordinate system. It is now routine to use the metaphor of energy landscapes when attempting to visualise how attractor networks operate.) Suppose we're parachuted into this landscape from on high. Let's imagine it looks rather like a landscape of hills and valley in Figure 1. We touch the ground, and start rolling. What will happen? We’ll roll to the lowest point in our vicinity. If we land near the bottom of a steep valley, it won’t take us long at all; if we land near the top of a hill that gently slopes down to a wide, shallow valley, it will take us some time to roll to the bottom. But roll to the bottom of the valley we will. Note that the valley bottom to which we roll will not be the lowest in the landscape (unless by chance we happen to have luckily parachuted onto the slopes of that particular valley); it will be the bottom of our local valley. This idea of a *local minimum* is an important one (Axelrod & Bennett, 1993).

Insert Figure 1 about here

In dynamical systems theories these valley bottoms, the points to which things in local space will gravitate, are called *attractors*. Attractors are defined in multi-dimensional space, with the dimensions of the space defined by the number of units at that level of representation, but for the past the number of dimensions will be enormous. Attractors are created by the mathematics of the system. The space can have one or many attractors: a useful analogy is that it can be described as one large valley, or two or more valleys. In every case the attractor to which you’re attracted depends on the current configuration of the state space. It’s important to note that attractors vary in size: some might be very large, covering a relatively large area of the landscape, or very small. We can think of these as corresponding to a very large valley having a large drainage basin, or smaller ones which cover a smaller area. Obviously if you’re parachuted at random into a landscape with many attractors, you’re more likely to end up in the larger basin, but not necessarily so. More strictly, the probability of to which attractor you fall is a function of the relative sizes of the attractors in that landscape. Different attractors can have walls of different slopes, too, just as in a real landscape some valleys are shallow and some steep. The steepness of the attractor wall defines how quickly you as parachutist will reach the bottom of the valley (the attractor); you'll roll more steeply down a steep mountain slope than down a gentle broad hill.

In models of the past, attractors determine historical outcomes. The Great War was an attractor, and probably one with a very large valley; many but not necessarily all events would have taken us to the attractor of devastating global conflict. The Great War with Britain standing against Germany was one attractor; the Great War with Britain remaining neutral or even alongside Germany another, albeit smaller, one. Certain outcomes may be very likely whatever the starting conditions. So according to this account, the War was very likely, or at least probable at that time, but not an absolute certainty.

The next step involves deviating from the comfort of our landscape analogy. While the geographical landscapes with which we are familiar are relatively stable, changing mostly imperceptibly in geological time, the topography of the historical attractor landscape is rapidly changing, perhaps chaotically so, evolving from time slice to time slice. We have landscape in rapid and constant motion. Even the rate of change of our landscape between time steps is unpredictable: sometimes it is as though we're moving in geological time and the landscape hardly changes at all, but at other times as though there's tectonic upheaval replete with earthquakes and massive volcanoes appearing each moment. It seems unlikely that whether you or I have a sandwich now or in five minutes is going to make much difference to anything, particularly global events (although in Princip's case it of course did). Both some events and some time periods are more critical than others. And some events are clearly going to have large effects. Most local effects don't perturb the landscape too much, but some might. So while there is persistence in the historical landscape, it can change dramatically from time to time.

So we conceptualise the unfurling of the past as an ever-changing attractor landscape. As events unfurl, the historical state space changes and evolves. Events move us stochastically through the changing landscape: even the chaos isn't stable. Nevertheless, there are attractors, but their size and stability vary and change, sometimes rapidly.

It is likely that in common with many other phenomena the frequency of occurrence of events of different magnitude is not random, but can be described by a power law, so that there is a linear relationship between the logarithm of the frequency and the logarithm of the magnitude of the event. The power-law relationship says far more than events with big consequences happen less often than events with small consequences; the relation is far more precise, so that, for example, events that are twice as big happen a quarter as many times as the smaller event (depending on the slope of the line). Power laws characterise many physical and biological systems, including psychology, with properties similar to those of the historical system in the way I have been describing it - self-organising systems.

The landscape analogy involves a three-dimensional space that evolves through time, but the past is staggeringly multi-dimensional. It is impossible to *visualise* this type of space. (Fortunately attractors in multi-dimensional space are mathematically tractable, with an attractor being defined as a minimum, that is as a point in space where the first partial derivatives of all variables are all zero, and the second partial derivatives at these points all positive, although the solution of the equations soon becomes very complex.)

Indeed, one of the challenges of this approach is to decide what are the appropriate variables that describe the multi-dimensional space that in turn best approximate to the system. What are the basic units of the past? Events? Time slices? Properties of humanity? I have already said that there are no obvious answers to these questions. All choices are arbitrary. As I have mentioned, even trying to characterise time and events in a historical context is exceptionally difficult, and to some extent involve knowing the answer, or at least constructing a narrative, which involves interpretation. Indeed, in addition to the values of our enormous number of variables changing, the variables themselves almost certainly change with time. The splendid game *Civilization* (Sid Meier) has it spot on: as history progresses one advance leads to another, but there is a degree of sequentiality. You can't have bombers without flight. The price of uranium is almost certainly going to be irrelevant to a primitive society, but could be extremely important to an advanced one.

Unfortunately we can't experiment directly with the past, because as Watts (2011) says, "history [in the sense of the past] is only run once" (although we can experiment with *history*; see Munslow & Rosenstone, 2004). We can't rerun events and see what happens if Princip sits down for in a restaurant, or if Operation Sea Lion had proceeded and Hitler tried to invade Britain in the autumn of 1940. In consequence it is impossible to distinguish between the chaotic and inertial views of history experimentally. Nevertheless we might be able to obtain some insight into the robustness of historical unfolding using computational modelling. We might not be able to experiment with the past directly, but we can model it.

Computational modelling in general has the great virtue that it forces us to be completely explicit about our assumptions. Many of the ideas I've described above should be clear when we create models. Although it is impossible to model the past completely, we can play with "toy" worlds to get a feel for the robustness of historical attractor landscapes. Let me reiterate that I am aware that any attempt to model the past and its alternatives will involve an enormous degree of simplification, even though the resulting models will nevertheless be complex. My claim is that this simplification will not cause us to lose any of the principles of interest.

The problem with modelling the past is that it is modelling in a vacuum. Unlike psychological phenomena, where we can test our models against rich data sets and make predictions about future behaviour, history is not amenable to this sort of reductionist approach. The first problem lies in the difficulty of reducing the complexity of the historical system in any “lawful” way in terms of the length of time and the number of variables in the system. The second problem is that reducing the complexity turns the account of the past into a narrative, with choices all along the way, a point readily acknowledged by post-modernist historians. The third problem is that even if we could reduce the complexity lawfully we would be very circumscribed in the sorts of predictions we could make. There has only been one outcome of the past: now. However, there are an extremely large number of possible historical interpretations of the past. We can’t try different configurations and see what happens; history is what we see. We can’t go back and start again with slightly different starting conditions and see what happens; but we could get some idea of how likely things that happen are with a suitable model. That is the best we can hope for, which again shows that it is a mistake to think that there can be any lessons from history. At best individuals can learn from their past mistakes and hope for the future.

Implications for history as a discipline

These limitations unfortunately imposed by reality lead to a lack of verifiability and falsifiability, the consequence of which is that history is not, and never can be, a science, even though modelling might cast brilliant light on the sorts of mechanisms operative as events unfurl (see Munz, 2004, for more on the relation between history and science). In many ways this conclusion is the same as that of Hayden White (1973): a historian has to make choices in interpretation, more akin to those made by a poet than a scientist, and places the historian in the realm of literary analysis (Brown, 2005). This statement is not to say that history is inferior to science, or that academics who pursue history are in some way inferior to scientists! However, the types of approach open to historians are circumscribed - not just in practice, but in principle.

What other implications are there for history as a discipline? In my view the notion that the present is essentially a random outcome from the past fits well with post-modernist accounts of history. It supports the idea, for example, that it is problematic to say that everything that happened in France pre-1789 led to 1789, and instead, as Barthes says "all history with an end-point is a myth" (Stafford, 1998). Or more precisely, and depressingly for historians, everything that had happened in the universe led to 1789, or 1914, or 1939, and it is hopeless to try to attribute the end of the story to any key events. The best we can do is deal with probabilities. Different historians will bring different viewpoints to their texts, and these different accounts all have their own reality. We can deconstruct all stories, but none is likely to be able to capture the truth of the complexity of the causal chain.

Although this claim is doubtless controversial, the construction of a historical narrative comes to involve the description of a series of accidents. The most insightful historical accounts will be those that show the role of these accidents in historical outcomes. Princip's sandwich should be given equal weighting to the balance of the military superpowers in 1914.

Conclusion

Would the Great War have still happened if Gustav Princip hadn't stopped outside Moritz Schiller's delicatessen just as the Archduke's car happened to reverse in front of him? Probably, yes, because the circumstances at the time - the ethnic tensions, the large militarised states engaged in an arms race, the lack of efficient diplomatic channels, and the legacy of recent conflicts had led to an unstable system where European conflict was a massive attractor. But events might have led to the attractor being avoided in 1914, only for a different attractor (a Russian attack on Germany perhaps) to develop a few years later. Dynamic attractors provide a useful way of thinking about history.

Are there "laws of history"? If a system is truly chaotic does it make sense to talk of causes? As ever the "truth" (in the colloquial sense of what really happened and why) lies between the ends of a false dichotomy. I have argued that the dynamic attractor landscape model suggests that history is a blend of chaos and inertia, so it does indeed sometimes make sense to talk of historical laws - not just historical accidents - at least in the form of a coherent narrative. A law is a configuration of events that leads to a relatively stable, large attractor over time. So the configuration that led to the Great War is amenable to a lawful analysis - or at last we can construct a plausible narrative about its origins.

What do dynamic attractors buy us? Are they anything more than a trivial redescription of the data? First, they provide a *vocabulary* to describe how the present unfolds in terms of probability and causation. Second, they are amenable to a mathematical and computational *analysis*. We can model what would have happened. However, we can do no better than deal in probabilities; the sheer number of variables determining the shape of a chaotic landscape, and the fact that the variables themselves change with time, make anything approaching a complete scientific account of history impossible. Third, they *describe* the way the past has unfurled, why the world is as it is today, and how it will change in the future.

Finally, what applies on the world stage, the narrative form of *macrohistory*, also applies to the individual, *microhistory*. Why are we as we are? How have we been affected are we our past? Would we have been totally different people if we had had baked beans instead of Brussels sprouts for dinner on our fifth birthday? What determines the narrative we tell about ourselves? The same concepts apply in both cases. Although the scale is smaller, the complexity of possible influences and outcomes is still staggering. Our dynamic attractor landscape is determined at birth by our genes and our environment, and from then external events and our choices shape the changing landscape. We have bifurcation points, where chaos reigns; slight changes in what happens can lead to enormous changes in one's life. A fraction of a second earlier or later and that fatal crash would never have happened. We can see these personal events stretching before us as a moment by moment, ever-changing chaotic landscape. On the other hand, it is likely that regardless of the many possible trajectories, I would still have become a scientist of some sort, and with lower but nevertheless still high probability, still become a psychologist, along many of them. Hence these outcomes were broad attractors for me. As with macrohistory, attractors change as we move along the bifurcating paths of the dynamic chaotic landscape, but some loom large and remain relatively stable over time.

Dynamic attractors are an exceptionally useful tool for thinking about the processes of the past, and the study of history could learn much from the study of the psychology of the individual. The problem is that there is a chaotic landscape out there, but it is for ever hidden from our view. It as though we are blind people mapping the lie of the land as it shifts beneath our feet. So for historians the lesson is that the causal story we tell about the past is just that: a story. So a perhaps paradoxical conclusion from the application of mathematical ideas to history is that the post-modern approach, where it's all in the narrative, is the most valid. There is a multiplicity of ways of describing the apparently causal sequences in the past, and there is no meta-narrative that could connect them (White, 1973); or, at best, these meta-narratives are highly speculative and descriptive (Munz, 1976, 1997). Instead what we have is *colligation*: we impose our explanations on the past. So in the words of Peter Munz (2004), "all history ... is story-telling" (p. 466).

Acknowledgements and contact details

I thank Gordon Brown, Seon Caimbeul, Chris Whatley, and two anonymous reviewers for their comments on an earlier draft of this paper. I must give a special mention to Alun Munslow, who gave particularly stimulating, helpful and copious comments that made this paper ultimately publishable. Please send any correspondence to: Professor Trevor Harley, School of Psychology, University of Dundee, Dundee DD1 4HN, or by email to t.a.harley@dundee.ac.uk.

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Word count:	9,759
Date of manuscript:	25-5-2012

Figure 1. An attractor network landscape.